Streaming and sound localization with a preceding distractor

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1. ABSTRACT

A previous study of sound localization with a preceding distractor showed that 1) the distractor affects response bias and response variance for distractor-target inter-stimulus-intervals of up to 400 ms, and that 2) localization responses are biased away from the distractor even on interleaved control trials in which the target is presented alone (Kopco et al., 2007). Neural mechanisms operating on time scales of milliseconds to tens of seconds are likely to cause to these effects.

The current study examined how perceptual organization affects target localization performance. Sound localization was examined for 2-ms click target stimuli. On 80% of trials the target was preceded by a distractor, designed either to be grouped with the target (distractor was an identical 2-ms click) or to be perceived in a separate stream (an isochronous train of 8 clicks whose inter-click-interval was different from the distractor-target inter-stimulus-interval).

As hypothesized, the single-click distractor affected target localization more than the 8-click distractor. On the other hand, the biases in the control trials were greater for the 8-click distractor. These results indicate that performance is influenced by both top-down mechanisms like streaming and bottom-up mechanisms like stimulus distribution-based adaptation.

2. CURRENT STUDY

Goals:

Replicate results of Kopco et al. (2007), add a condition in which the original (1-click) distractor is replaced by an 8-click distractor expected to induce streaming.

Hypotheses:

H1. Effects of distractor in Kopco et al. (2007) were mainly due to grouping of distractor and target. Therefore, streaming in the current study will reduce the response biases and variance due to the distractor.

H2. Contextual biases in Kopco et al. (2007) were mainly due to bottom-up mechanism sensitive to stimulus distribution. Therefore, the 8-click distractor will cause larger biases since it changes the stimulus distribution even more.

3. METHODS

Tasks:

On each trial, subjects pointed to the heard location of a target click presented from a random loudspeaker (Fig. 1).
On most trials, a "distractor" click preceded the target.
On control trials, the target was presented alone.
Inter-click-interval in 8-click distractor: 100 ms.
Distractor type and distractor-target Stimulus Onset Asynchrony (SOA):

- **Experiment 1 (Kopco et al., 2007):** 1-click; 25, 50, 100, 200, or 400 ms.
- **Experiment 2 (current study):** (1-click or 8-click) x (50 or 200 ms)

Experimental procedure

Each experiment in two different environments: reverberant classroom (background noise of 40 dBA) or anechoic space
Seven normal-hearing subjects in classroom (four in anechoic space)
Seven target loudspeakers and two distractor loudspeakers positioned in the subjects' right (or left) frontal quadrant (see Fig. 1)
Runs blocked by distractor location (frontal or lateral) and listener orientation (left or right quadrant).
Four 1-hour sessions per experiment per subject
Each session was 4 runs of 168-trials (random order) in Experiment 1 and 144 trials in Experiment 2.

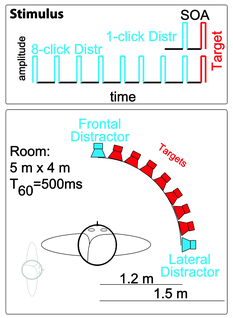

Fig. 1. Experimental stimuli and setup

Data Analysis

Assumed left/right symmetry - data collapsed across orientation. Outliers lying 23° and more from a within-run median were removed. For each subject, mean response azimuth and standard deviation were calculated.

4. RESULTS: Raw data

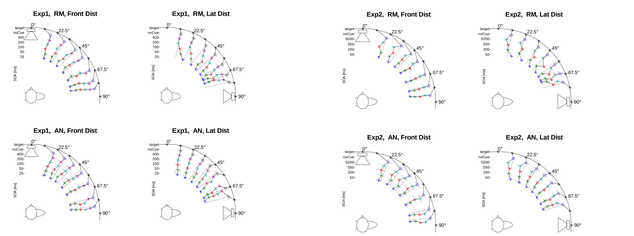

Fig. 2. Mean localization responses in the classroom (top row) and the anechoic room (bottom row) in Exp. 1 (left-hand panels) and Exp. 2 (right-hand panels). Each panel shows the across-subject mean and standard error in perceived target lateral angle as a function of actual target lateral angle for different SOAs and distractor types (as well as in the no-distractor condition). Frontal distractor is in columns 1 and 3. Lateral distractor in columns 2 and 4.

5. RESULTS: Mean Response

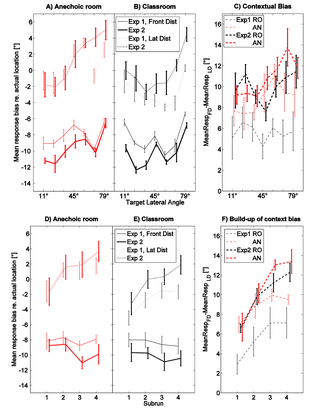

Fig. 3. Across-subject mean and within-subject standard error in the no-distractor data from Exps. 1 & 2 plotted as a function of target speaker (top row) and experimental subrun (bottom row; averaged across target). Panels A, B, D, E show data separately for frontal and lateral distractor runs. Panels C and F show difference between frontal and lateral data.

Response bias in no-distractor control trials (Fig. 3A, 3B)

In both Exps and both rooms, no-distractor responses are shifted
- frontally in lateral-distractor runs,
- laterally in frontal-distractor runs.

In both rooms, streaming causes larger shifts for nearby sources. Thick lines are
- above thin lines at right-hand side for lateral distractor,
- below thin lines at left-hand side for frontal distractor.

Difference in biases between frontal distractor and lateral distractor data (Fig. 3C)

Differences are:
- independent of target location,
- larger for streaming (Exp. 2),
- larger for anechoic room, especially in Exp. 1.

Build-up of contextual bias (Fig. 3D-F)

Bias grows over time
- more for lateral distractor than frontal distractor data (Fig. 3D, 3E)
- at least 50% of it done by subrun 1 (Fig. 3F)
- saturates by subrun 3 in Exp. 1, grows in subrun 4 in Exp. 2 (Fig. 3F)
- 4-way RM ANOVA performed on difference data found significant 3-way interaction of Experiment, Room, Subrun ($F_{3,9}$=5.03, p=0.026).

Context induces bias:
- larger with 8-click than 1-click distractor (especially near the distractor),
- larger in anechoic space for 1-click distractor,
- growing over time mainly for the lateral distractor,
- growing more with 8-click distractor,
- influenced by presence of reverberation.

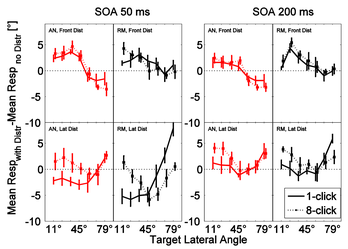

Fig. 4. Effect of distractor on the response target lateral angle in Exp. 2. Across-subject mean and standard error in the difference between the response lateral angle with the distractor vs without the distractor. Each panel shows results of 1-click and 8-click distractor for a different SOA.

Effect of distractor (Fig. 4)

1-click lateral distractor (solid lines, bottom row):
- attracts frontal targets for 50-ms classroom, less in anechoic room,
- repulses lateral targets at both SOAs, more in classroom.

1-click lateral and frontal distractor causes:
- attraction in the middle of response range, in both rooms and stronger at shorter SOA.

1-click results in Exp. 2 similar to Exp. 1 (Exp. 1 data not shown).

8-click lateral distractor re. 1-click (squares vs. solid lines, bottom row):
- eliminates the bias for frontal targets for 50-ms classroom,
- eliminates the frontal bias for lateral targets in classroom,
- shifts all frontal target responses away.

8-click frontal distractor (top row):
- causes effects similar to 1-click frontal distractor.

Streaming reduces the effect of distractor on target localization, in particular for lateral distractor in the classroom.

6. RESULTS: Response Variance (Exp. 2)

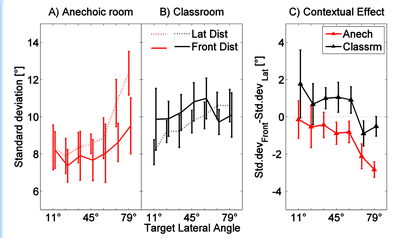

Fig. 5. Response standard deviation in the no-distractor trials as a function of target azimuth, separately for the frontal and lateral distractors in the anechoic room (A), classroom (B). Panel C shows the difference between frontal-distractor and lateral-distractor data for both rooms.

Response st. dev. in no-distractor control trials

In anechoic room (Fig. 5A), no-distractor st. dev.
- increases with target laterality,
- is larger for lateral than frontal distractor.

In classroom (Fig. 5B), no-distractor st. dev.
- tends to be larger than in anechoic room,
- is similar for the two distractor locations,
- varies less with target laterality.

Difference (Fig. 5C)
- is negative for lateral targets in anechoic room,
- is negligible in classroom.

Results for Exp. 1 are similar (data not shown).

Context affects response variability in anechoic room, but not in classroom. Lateral distractor context increases no-distractor response variability for nearby sources (re. frontal distractor).

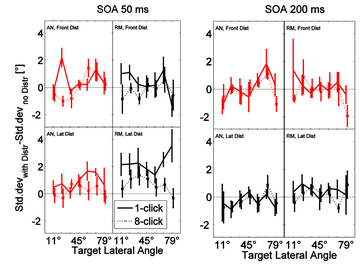

Fig. 6. Effect of distractor on the response st. dev. as a function of target location in Exp. 2. Across-subject mean and standard error in the difference between the response st. dev. with the distractor vs. without the distractor. Each panel shows results of 1-click and 8-click distractor for a different SOA, room, and distractor location.

Effect of distractor on response st. dev. (Fig. 6)

50-ms SOA, 1-click distractor
- lateral distractor increases response st. dev.,
  - a lot in classroom, in particular for lateral targets,
  - less in anechoic room.
- frontal distractor has a much smaller effect, mostly on frontal targets.

50-ms SOA, 8-click distractor
- eliminates most of st. dev. due to 1-click distractor,
- in particular for targets near distractor.

200-ms SOA – no effect of either distractor.

1-click data similar to Exp. 1 (data not shown).

Response variance is increased by 1-click distractor. **Streaming** eliminates most of this variance increase.

7. CONCLUSIONS AND DISCUSSION

A preceding distractor has a complex effect on azimuthal localization of a target click stimulus. This effect is influenced by whether the distractor is likely to be **grouped** with the target (1-click) or processed in a separate **stream** (8-click).

EFFECT OF DISTRACTOR (H1)

A 1-click **distractor induced** 3 types of **bias** in Kopco et al. (2007). Here, streaming eliminated 2 of them. Therefore, these biases were due to perceptual organization and/or reverberation processing, not acoustic/peripheral interactions. In addition, 8-click lateral (but not frontal) distractors caused frontal biases for frontal targets (re. 1-click distractor). This effect might be related to perceptual effects like inhibition of return (Spence and Driver, 1998).
The variance induced by a 1-click **distractor** was nearly eliminated by streaming (8-click distractor), especially for a 50-ms lateral distractor in a classroom. This, again, supports the hypothesis that the effect of a 1-click distractor is likely due to perceptual organization and precedence-like reverberation processing (Freyman et al., 1991).

EFFECT OF CONTEXT (H2)

Contextual bias induced by an 8-click distractor is stronger than that induced by a 1-click distractor, and is larger in a classroom than in an anechoic room. This finding is consistent with a bottom-up adaptation mechanism sensitive to the distribution of stimuli (Kopco et al., 2015). However, the mechanism shifts responses away from the stimulus distribution centroid (cf. Dahmen et al., 2010). Also, it cannot explain why frontal and lateral distractors have different effects.
Context has an effect on response standard deviation only in the anechoic room, where a lateral-distractor context increases response variance for lateral targets (re. frontal-distractor context). This effect is similar for 1-click and 8-click contexts. A precedence-effect-buildup-like mechanism might explain this result. However, it is not clear why a frontal distractor does not lead to an analogous effect for frontal targets.

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